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EDGEWOOD ARSENAL CONTRACTOR REPORT

EM-CR-76030

Report No. 3

ESTIMATING EXTERNAL BLAST LOADS FROM SUPPRESSIVE STRUCTURES

by

E. D. Esparza

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Contract No. DAAA15-75-C-0083

DEPARTMENT OF THE ARMY

Headquarters, Edgewood Arsenal

Aberdeen Proving Ground, Maryland 21010
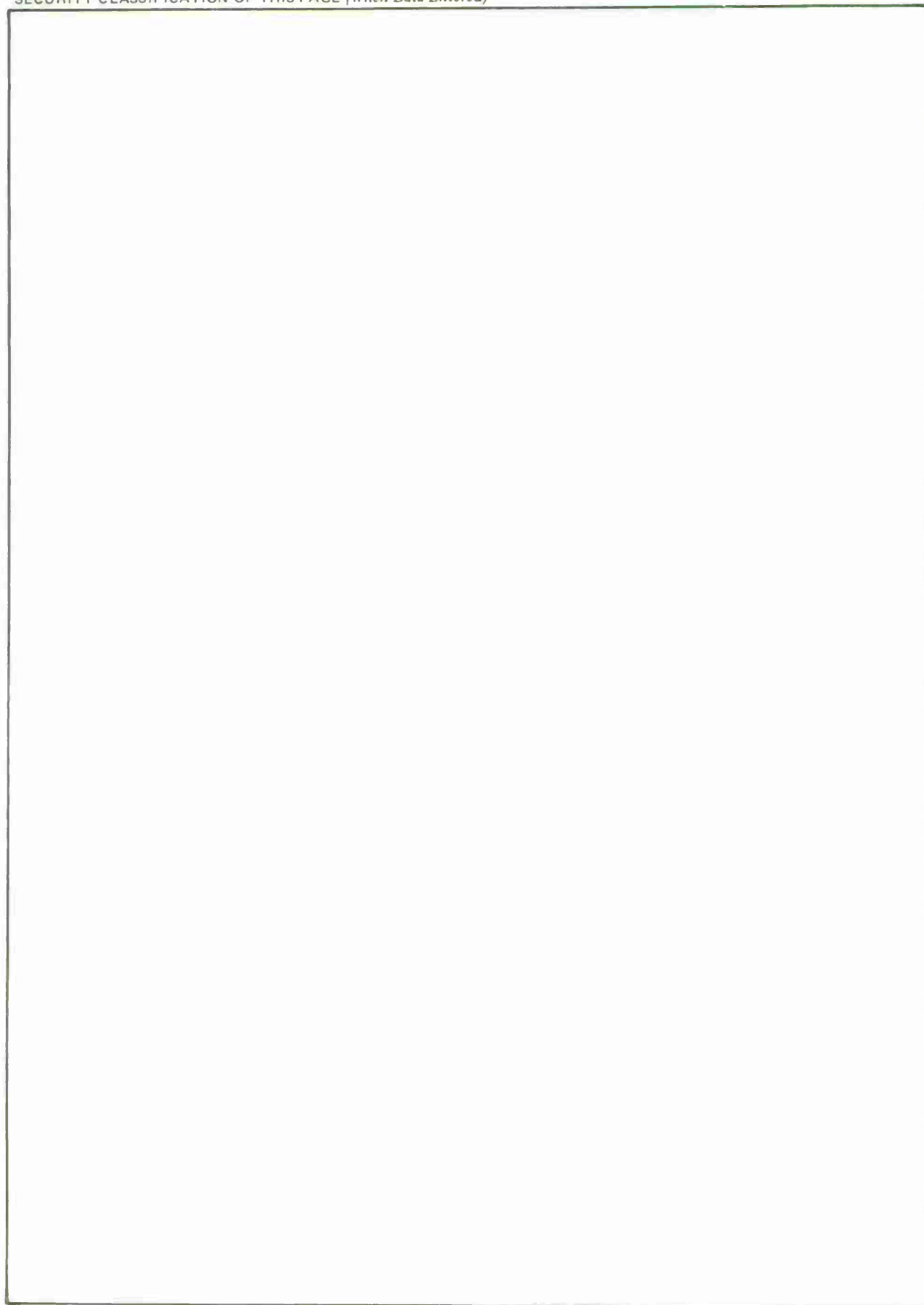
SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER EM-CR-76030	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* ESTIMATING EXTERNAL BLAST LOADS FROM SUPPRESSIVE STRUCTURES		5. TYPE OF REPORT & PERIOD COVERED Technical Report Sept. 1974 to July 1975
		6. PERFORMING ORG. REPORT NUMBER No. 3
7. AUTHOR*(s)* E. D. Esparza		8. CONTRACT OR GRANT NUMBER*(s)* DAA-15-75-C-0083
9. PERFORMING ORGANIZATION NAME AND ADDRESSES Southwest Research Institute P. O. Drawer 28510 San Antonio, Texas 78284		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PA, A 5751264
11. CONTROLLING OFFICE NAME AND ADDRESS Commander, Edgewood Arsenal Attn: SAREA-PR-W Aberdeen Proving Ground, Maryland 21010		12. REPORT DATE November 1975
		13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* Commander, Edgewood Arsenal Attn: SAREA-MT-H Aberdeen Proving Ground, MD 21010 (CPO Mr. Bruce W. Jezek, 671-2661)		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Suppressive shields   Blast scaling
External blast   Effective vent areas
Blast attenuation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report describes methods for predicting blast overpressure outside suppressive structures. Prediction curves are in scaled form. Data are compared to free-field data for large high-explosive detonations on the ground.

SUMMARY

This report describes methods for predicting blast overpressures outside suppressive structures of various sizes with a variety of vented panel configurations. The prediction curves are presented in scaled form, based on a previously developed model law. Free-field data are compared to scaled data from large high explosive detonations on the ground. Results are tentative because of continuing experimental work which may modify the curve fits given in the report.

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I. INTRODUCTION

Suppressive structures are intended to attenuate the blast waves transmitted through their walls to levels which will minimize damage to other nearby structures or injury to nearby personnel. Accordingly, most of the past and planned tests of suppressive structures include measurements of the blast fields over a range of distances from their outer surfaces. Such data have usually been compared to blast pressures measured from the same blast sources without the suppressive structure, or to compiled data on air blast. The data from many different experiments can be scaled, however, and placed on a common basis to extend the range of prediction of blast attenuation for structures of different size, attenuating panel design, or explosive charge weight. In this report, we develop prediction equations for side-on blast overpressures outside suppressive structures with a variety of panel designs, based on a blast scaling law.

The work reported here was conducted for Edgewood Arsenal under Contract DAAA15-75-C-0083 as a part of the suppressive structures program.

II. ANALYSIS

The methodology for developing equations to estimate the side-on overpressure at a location outside of a suppressive structure is presented in Reference 1. However, since some of the parameters used to determine an expression for side-on pressure have subsequently been slightly redefined, an abbreviated analysis will be presented here.

The free-field relationship for side-on overpressure P_s is given by the Hopkinson-Cranz scaling law for geometrically similar sources at sea-level ambient atmospheric conditions as

$$P_s = f\left(\frac{R}{W^{1/3}}\right) \qquad \text{(free field)} \tag{1}$$

Using a similar analysis to derive a functional expression for the side-on overpressures outside of a suppressive structure, we have

$$P_s = f_1\left(\frac{R}{W^{1/3}}, \frac{X}{R}, \alpha_e\right) \tag{2}$$

where

P_s — side-on pressure (psi)
$Z = R/W^{1/3}$ (ft/lb$_m^{1/3}$)

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R – distance from charge (ft)

W – charge weight (lb)

X – characteristic length of structure (ft)

For square walls, X = side dimension

For rectangular walls, X = square root of wall area

α_e – effective vent area ratio (-)

$L = R/X$ (-)

To compute α_e for N-layered, multiwalled structures, we have assumed that

$$\frac{1}{\alpha_e} \quad \sum_{i=1}^{N} \quad \frac{1}{\alpha_i} \tag{3}$$

This relationship has at the moment no theoretical proof. However, it does reach the appropriate limits for small and large number of plates, and provides a relative measure of venting for a variety of panel configurations. For each vented member in a panel, α is defined as

$$\alpha_1 = \left(\frac{\text{Vent Area}}{\text{Wall Area}}\right)_1 , \frac{A_{V_2}}{A_W} , \ldots \tag{4}$$

For perforated plates, the meaning of Equation (4) is obvious; however, for angles and louvres, the definition is less obvious. Figures 1 and 2 show the present definition of α for these two members.

Now that all the parameters in Equation (2) have been defined, this equation is assumed to have the form

$$P_s = A \ (Z)^{N1} \left(\frac{X}{R}\right)^{N2} (\alpha_e)^{N3} \tag{5}$$

which will allow least-squares fitting to experimental data. Taking logarithms of both sides, a least-squares curve fit can be developed using the experimental data and stating that

$$\left[1.0, \ln Z, \ln \frac{X}{R}, \ln \alpha_e\right] \begin{bmatrix} \ln A \\ N1 \\ N2 \\ N3 \end{bmatrix} = [\ln P_s] \tag{6}$$

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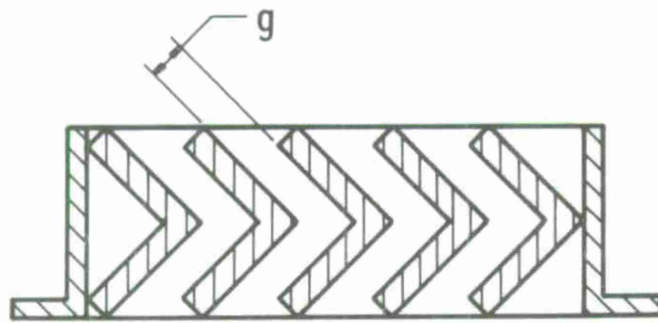
SECTION A - A
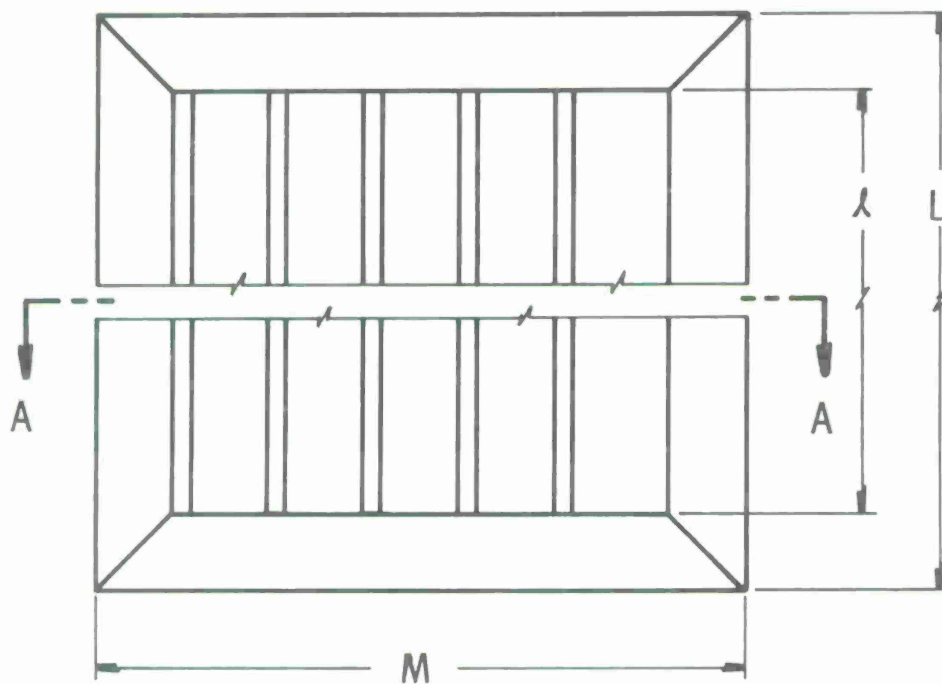
$$A_{vent} = J \ell g \ , \quad J = \text{NUMBER OF OPENINGS}$$

$$A_{wall} = LM$$

$$\alpha = \frac{A_{vent}}{A_{wall}}$$

FIGURE 1. DEFINITION OF α FOR A LAYER OF ANGLES

SECTION A - A
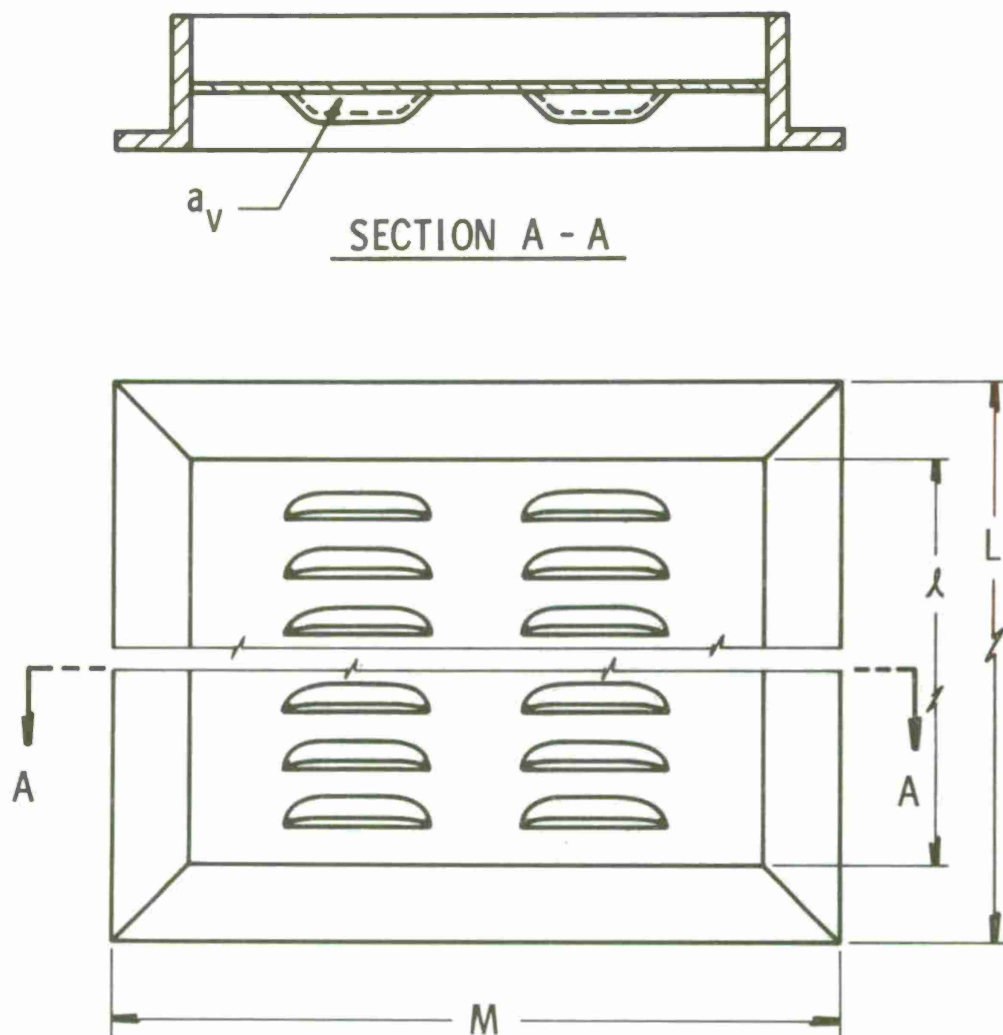
$A_{vent} = Ka_v$, K = NUMBER OF LOUVRES

$A_{wall} = LM$

$$\alpha = \frac{A_{vent}}{2\,A_{wall}}$$

FIGURE 2. DEFINITION OF α FOR LOUVRES

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or, substituting matrix notation,

$$[L] \; [N] = [P] \tag{7}$$

A least-squares curve fit results for the N matrix ($\ln A$, $N1$, $N2$, and $N3$) when

$$[N] = [L^T L]^{-1} [L^T] \; [P] \tag{8}$$

III. RESULTS

Before any curve fitting was done, all the original NSTL data used to derive the previous expression P_s (see Reference 1) was rechecked to make sure that it was on a common base. Particular attention was given to computing α_e and X. However, because in several cases panel drawings were not available, the vent areas for each panel member were taken to be those which were stated in the texts of References 2, 3, and 4. The resulting equation from curve fitting the experimental data from these reports is

$$P_s = 677.5 \frac{L^{0.485} \; \alpha_e^{0.537}}{Z^{1.84}} \tag{9}$$

Figure 3 is a plot of Equation (9) versus the experimental data points used to compose this plot. This equation appears to curve fit the test results very well. The estimate of the standard deviation, S, for the experimental data about the line equals ±20% which is only slightly worse than the spread obtained for similar free-field data. *Because this is a curve fit to test data, Equation (9) should only be used when input conditions fall within variations in the individual pi terms.* The variations in the test results were:

$0.55 \leqslant L \leqslant 3.09$
$0.025 \leqslant \alpha_e \leqslant 0.60$
$4.29 \; \text{ft/lb}_m^{1/3} \leqslant Z \leqslant 15.5 \; \text{ft/lb}_m^{1/3}$

Taking the free-field side-on pressure data from the same three references and curve-fitting using the same procedure over a similar range of Z as for the suppressive structure pressure data, the resulting equation is

$$P_s = \frac{962.3}{Z^{2.057}} \tag{10}$$

Figure 4 compares Equation (10) and the data points. This equation appears to curve fit the test results excellently with an S of ±13% which, as would be expected, is slightly better than the fit for the suppressive structure blast field. Naturally, Equation (10) should only be applied whenever Z varies as follows:

$$4.29 \; \text{ft/lb}^{1/3} \leqslant Z \leqslant 15.9 \; \text{ft/lb}_m^{1/3}$$
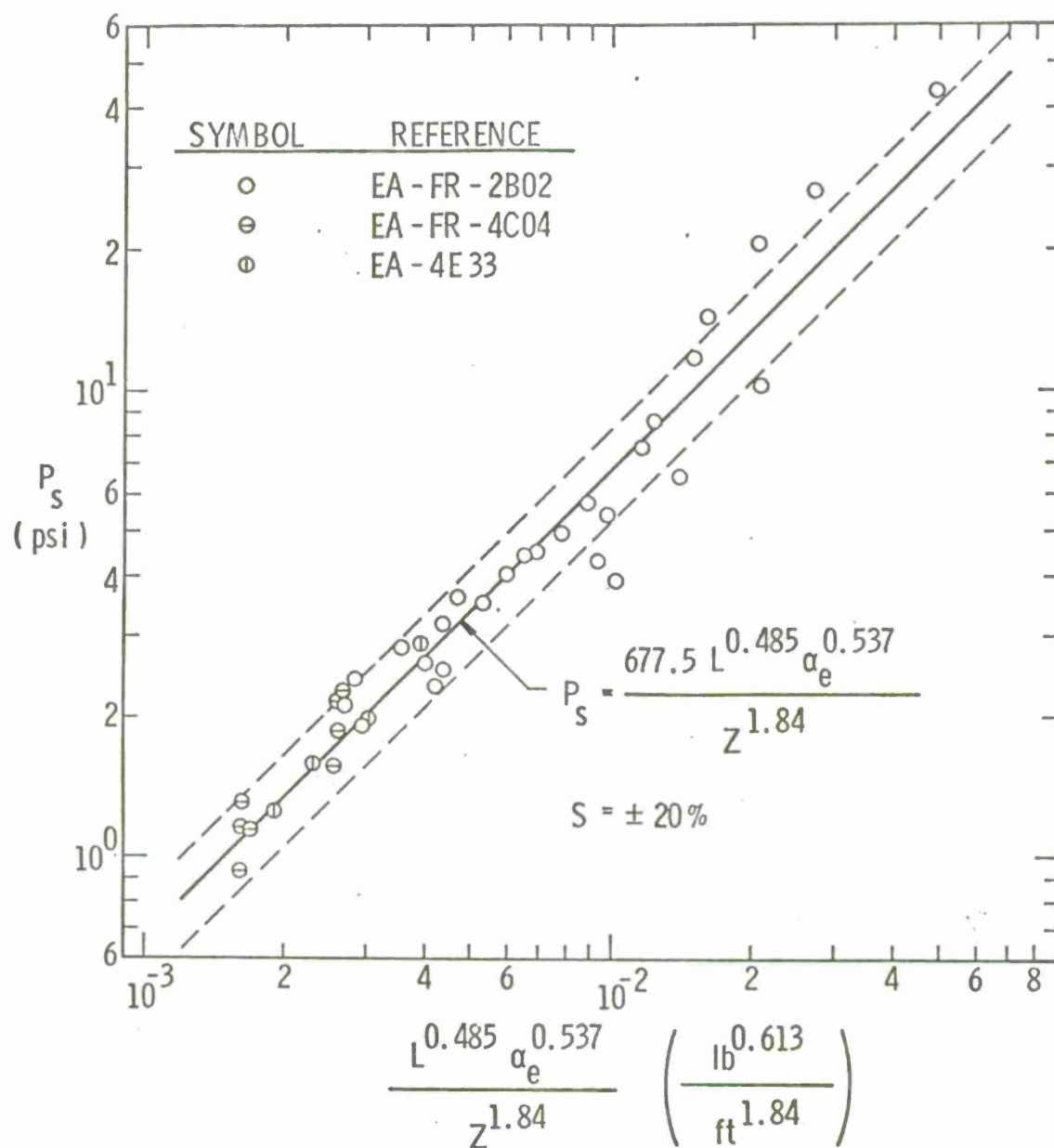
FIGURE 3. CURVE FIT TO BLAST PRESSURES
OUTSIDE NSTL STRUCTURES
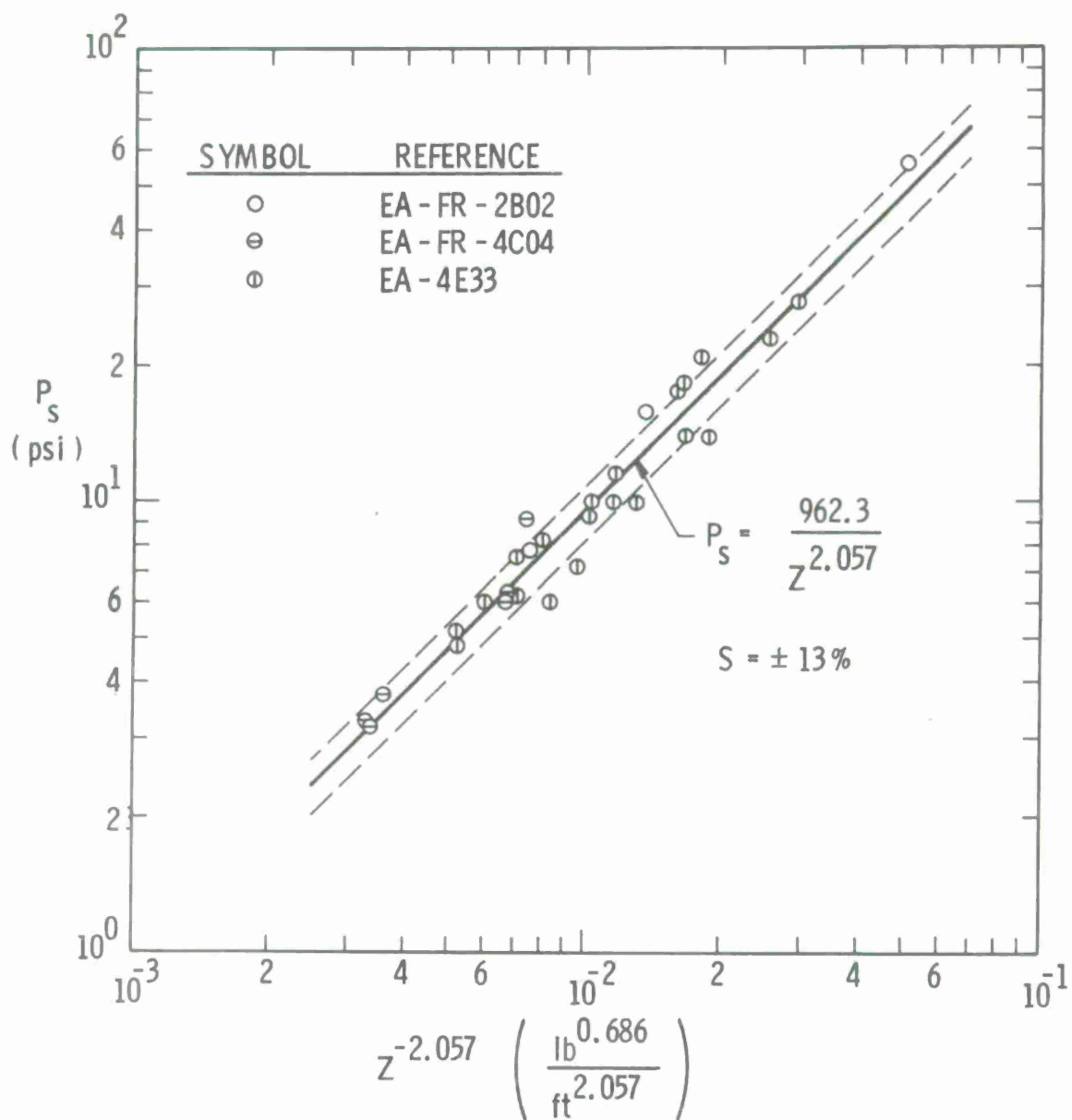
FIGURE 4. CURVE FIT TO NSTL FREE FIELD
BLAST PRESSURES

It is interesting to see how additional free-field data points from tests using charge weights which are orders of magnitude larger than those used to generate the NSTL data, will affect the curve fit. Using data from four different large-scale field tests [5, 6] which fall within the same range of Z used previously results in

$$P_s = \frac{1089.2}{Z^{2.098}} \tag{11}$$

Figure 5 compares this equation with all the data points used and shows an excellent fit with an S of $\pm13\%$.

Comparing Equations (10) and (11), one can see that they are almost identical. As a matter of fact the side-on pressure predicted by these equations would differ by a maximum of only 6.2% at a Z of 4.29 ft/$lb_m^{1/3}$. This difference decreases to an insignificant 1% at the upper limit of Z (15.9 ft/$lb_m^{1/3}$).

IV. DISCUSSION AND CONCLUSIONS

It must be emphasized again that in using the empirical equations in this report, the limits given for the individual pi terms must be satisfied. *If large extrapolations are attempted beyond these limits, gross errors will certainly occur in estimating P_s.* For example, as a blast wave propagates to great distances from its source, it travels at essentially the speed of sound and, assuming homogeneous, still air, the pressure in the front would decrease as the inverse of the distance R (or as a function of $1/Z$).[7] However, for the data range used here to obtain the free-field equations, the pressure is decreasing approximately as the inverse of the distance squared.

Work in measurement of blast pressures outside suppressive structures is continuing apace, and the results presented here will certainly be updated and extended in coming months. In particular, sufficient data for side-on impulse should soon be available to establish fits similar to those given here for side-on overpressure, and data will be available for other panel configurations such as interlocked I-beams. The equations and curves presented here must therefore be considered as interim ones, to be supplemented or supplanted as later data becomes available.

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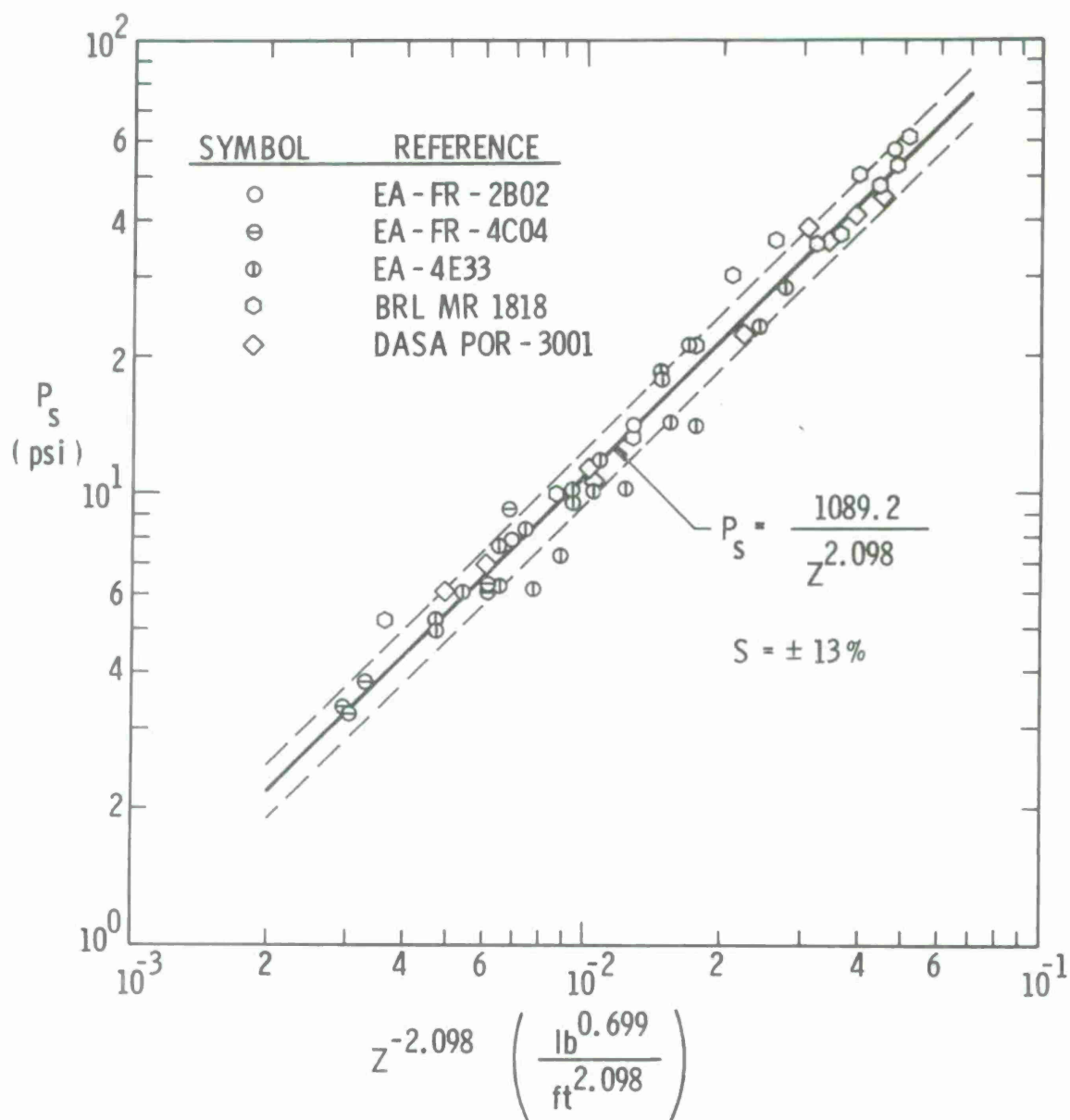
FIGURE 5. CURVE FIT TO NSTL, SNOWBALL AND FLAT TOP
FREE FIELD BLAST PRESSURES

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